HARQ Performance Analysis of a Long-Term Evolution System

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Abstract—**This study investigated an existing cellular wireless communication system and found that the system performance was severely limited by co-channel interferences (CCI) within the cell and from users of other cells. Therefore, in addition to simulating the shadow fading and path loss models caused by the attenuation of wide-range signals and the Rayleigh fading caused by the attenuation of short-range signals required for general channel exploration, a co-channel interference model was also constructed. Finally, a structured simulation method is presented in the Conclusion section.**

Keywords- Hybrid automatic repeated request (HARQ); interference; co-channel; chase combining; high-speed factor mobility.

I. INTRODUCTION

Wireless communication has numerous advantages. However, various attending interferences and channel attenuations can cause packet transmission failures. Therefore, various retransmission mechanisms have been proposed to ensure transmission accuracy. Generally, two types of retransmission mechanisms exist. One mechanism is automatic repeat requests (ARQs). However, the disadvantage of ARQs is that a status report is not provided at the time the packet is lost, significantly delaying verification that a packet has been lost. The other retransmission mechanism is hybrid ARQ (HARQ). HARQ [7] integrates forward error correction and ARQ technology and can retain useful information from previous failed save attempts for subsequent decoding. During communication, the base station obtains the channel's status information through the positive or negative acknowledgments (ACK/NACK) returned in every transmission time interval and through the channel quality indicator (CQI).

In Chapter 2, this study achieved long-term evolution (LTE) [1-6] of the co-channel and other interference model environments. In Chapter 3, various signal-to-interference ratio (SIR) to symbol error rate (SER) graphs under modulation and coding schemes (MCS) were introduced and an error judgment system for the basic retransmission units of HARQ was developed. In Chapter 4, various parameter combinations were tested to obtain the final simulation results. In Chapter 5, the conclusion and future implications of this study are presented.

II. SIMULATION ENVIRONMENT

In cellular systems, service coverage can be divided into smaller geographical areas, called cells. The strength of the base stations' power output is controlled and limited within the parameters of their prospective cells to minimize interference. However, the space barrier created by the propagation path loss can cause the same frequency to be distributed to various cells. In reality, perfect spatial separation between cells is impossible. Frequency overlaps can lead to the co-channel interference phenomenon [6]. The communication system within the base station determines what frequency reuse factor to employ based on the degree of interference between the base stations. If one base station uses a large frequency reuse factor, base stations using the same frequency at far distances will have less co-channel interference if they employ a small frequency reuse factor. The smaller the frequency reuse factor, the more times the frequency band can be used; therefore, services can be provided to more users. However, this objective is extremely difficult to achieve.

This study focuses on cell interferences for eight co-channels under a slanted fractional frequency reuse (FFR) area within the cell parameters of a mobile station, as shown in Fig. 1.

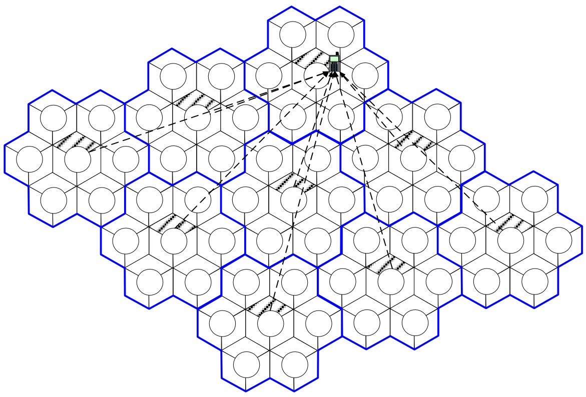

Figure 1. The Co-channel Interference Simulation Diagram Referenced for this Study

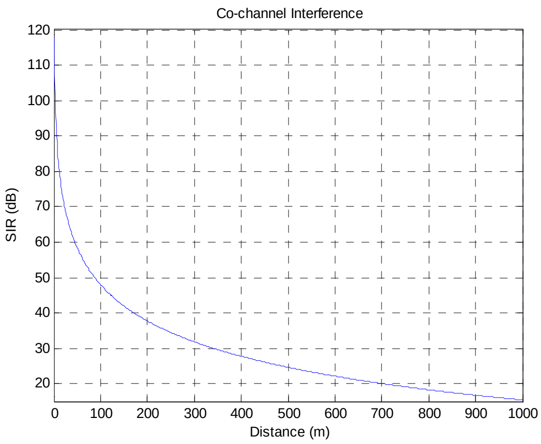

Figure 2. SIR Co-channel Interference Variations

TABLE I. LTE SYSTEM SIMULATION PARAMETERS

Path Loss Parameter		Rayleigh Parameter	
Model	COST231 HATA	*System BW*	10 MHz
BS Tx Power	46 dB	*Carrier Frequency*	2 GHz
Shadow Fading Parameter		*Sampling Frequency*	15.36 MHz
Lognormal Fading Constant	8 dB	*Symbol Time*	83.33 us
Co-channel Parameter		*RU Size*	12 x 6
Cell Size	750 m		
Reuse Factor	7		

Fig. 2 displays the SIR size schematics simulated by the eight co-channel interferences at various distances within a 750-m radius from the cell, as shown in Fig. 1. The 300-m and 600-m locations were selected as reference points for the simulated SIR levels.

This study simulated a mobile user within the FFR region of a cell with 10 resource units (RU) allocated to this user. The channel changes during each symbol time as the user moves was calculated to obtain the SIR value as each sub-carrier modulated its signal. These values were then employed in Chapters 3 and 5. Table I presents the LTE system simulation parameters.

III. HARQ

Fig. 3 is a system block diagram of the specially designed channel of the FFR system environment explored by this study However, this system diagram does not include the retransmission operating mechanism, and was only created to enable the SIR to SER graph to be simulated with various speeds, modulations, and coding. During the HARQ operation conducted in Chapter 5, when choosing the retransmission mechanism, the corresponding SIR to SER graph was also selected based on the MCS transmission level. The long-term evolution system uses the 12*6 version of the Resource Block with predetermined configurations, as shown in Fig. 4. The channels used in this study are the Path Loss Model: using the COST231 HATA Model and the Shadow Fading Model. Considering the situations for the city, the standard deviation for the Shadowing Fading Model and the 8dB Fast Fading Model were used. The study also used different sampling frequencies to explore the different speed variations and Co-channel Interference Models for the LTE. For the FFR, the reuse factor of 7 and the Co-channel Model with an eight-cell Co-channel Interference Model were considered. Eventually, the SIR to SER curve graph produced by the LTE system with three speeds (3km/hr, 80km/hr, 350km/hr) and six MCS are shown in Figs. 5, 6, and 7. The LTE parameter configuration produce better error curve results during moderate-high speeds at 16qam1/2, 16qam3/4, 64qam2/3, and 64qam3/4.

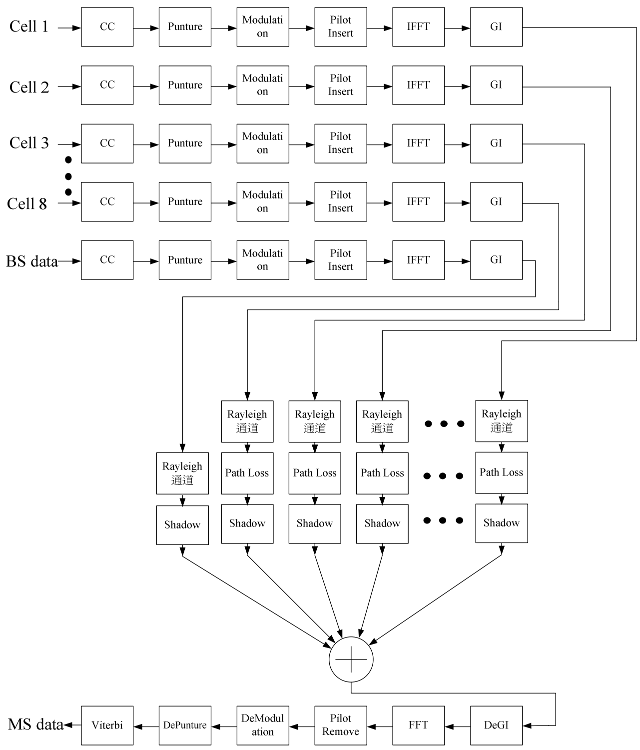

Figure 3. AMC System Model Diagram

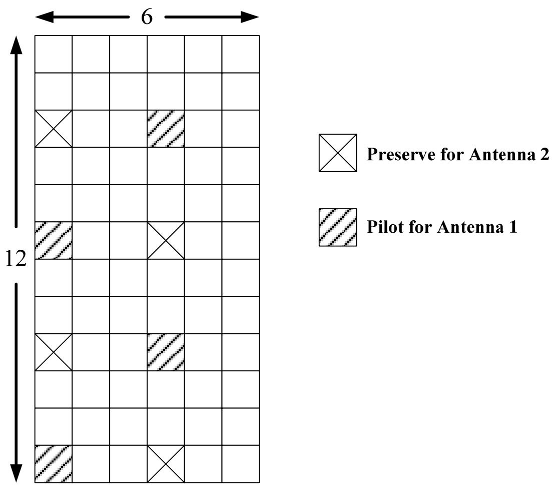

Figure 4. LTE Resource Block Pilot Structure

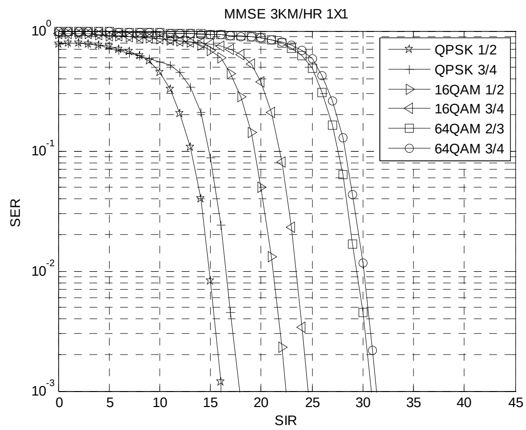

Figure 5. LTE 3km/hr SIR to SER Curve Graph

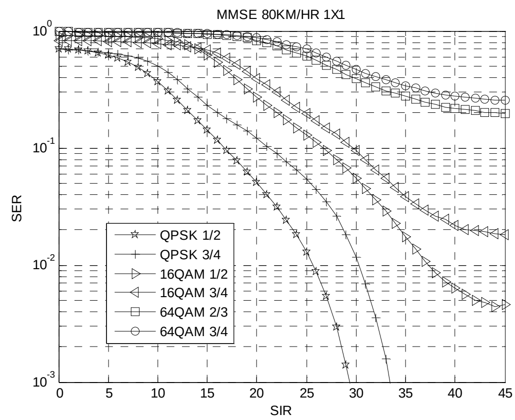

Figure 6. LTE 80km/hr SIR to SER Curve Graph

IV. SYSTEM SIMULATION

The HARQ examined in this study was a frequency-division duplexing (FDD) downlink situation. Therefore, the co-channel interference experienced by the MS in the demand base station is influenced only by the base station within the same cell of the co-channel interference and not by other MS in the same cell of the co-channel interference. Asynchronous adaptive HARQ was considered for the LET downlink. For asynchronous situations, the retransmission unit can be arranged under other sub-frames and can support multi-HARQ processes simultaneously, which is impossible for the synchronous system. The only requirement is that the transmission delay time is satisfied. Fig. 8 shows the LTE system frame structure.

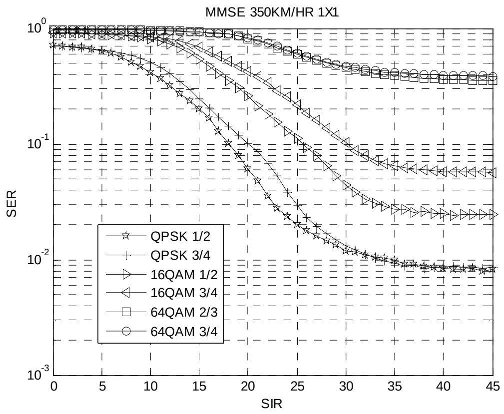

Figure 7. LTE 80 km/hr SIR to SER Curve Graph

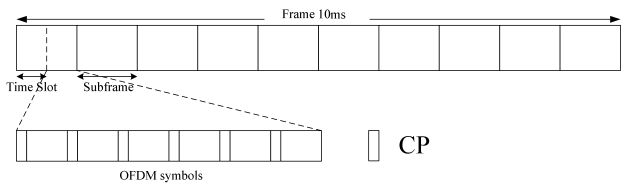

Figure 8. LTE Frame Structure FDD

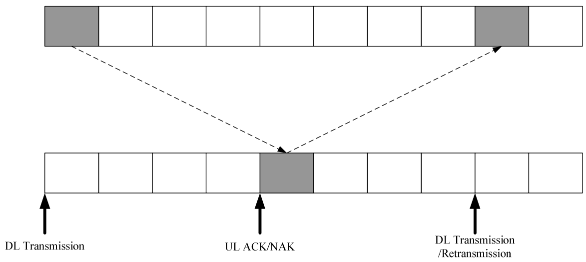

Figure 9. LTE HARQ Operational Timing

The LTE system has three TTI delays during uplinks and downlinks, and the ACK/NACK consumes one TTI, as shown in Fig. 9. Regarding buffers, the original packet is not discarded until the ACK is received. The gray boxes in Tables II, III, and IV are caused by a PER over 10%; therefore, the system cannot be employed under the specification requirements.

V. CONCLUSION

This study proposed a HARQ structured simulation method that divides services into four segments, and each segment can be upgraded differently in the future based on various needs. A FFR co-channel and a high-speed factor system simulation environment that can be altered according to the system needs in the future were also developed. Besides employing the EMD provision method to include shadowing, the speed impact factor was also incorporated. Independent research of this topic should be conducted to examine the addition of variable speeds and to serve as a basis for simulating the speed variations of high-speed rail. Retransmission has become the optimum method to obtain the SIR to SER error curve graph under various retransmission frequencies and MCS levels. Therefore, independent system upgrades, such as adopting the real 4G system or including new retransmission methods, can be implemented in the future by changing to CTC IR with bit-level soft combining or other retransmission techniques.

ACKNOWLEDGMENT

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TABLE II. LTE SYSTEM WITH A DISTANCE OF 300 M AND A SPEED OF 3 KM/HR

LTE, Distance = 300 m, Speed = 3 km/hr, and Buffer = 1280 Bytes								
MSC Data	Retransmission Method	MCS Retransmission Method	Theoretical Data Transmission Rate (kbps)	Actual Data Transmission Rate (kbps)	Greatest Buffer Demands (Bytes)	Instances of Transmission	PER	Data Transmission Ratio
QPSK1/2	Chase Combining	Same	1040.00	1026.71	957	778	0.00000	1
	Type I	Same	1040.00	1025.38	1040	855	0.00000	1
QPSK3/4	Chase Combining	Same	1680.01	1595.74	531	834	0.00000	0.95
	Type I	Same	1680.01	1595.74	565	994	0.00024	0.95
16QAM1/2	Chase Combining	Same	2320.01	2197.52	1198	2085	0.00143	0.95
	Type I	Same	2320.01	2083.57	1183	2554	0.00572	0.9
		QPSK1/2	2320.01	1968.46	1038	1283	0.00021	0.85
16QAM3/4	Chase Combining	Same	3600.01	2339.63	1197	3809	0.00673	0.65
	Type I	Same	3600.01	1979.68	1170	4639	0.01702	0.55
		QPSK3/4	3600.01	1979.68	1170	2305	0.00066	0.55
64QAM2/3	Chase Combining	Same	4880.02	1458.51	970	13032	0.09989	0.3
	Type I	Same	4880.02	1452.10	1159	16544	0.18055	0.3
		16QAM1/2	4880.02	1461.13	1007	6545	0.01033	0.3
		QPSK1/2	4880.02	1209.69	1220	4012	0	0.25
64QAM3/4	Chase Combining	Same	5520.02	1374.82	828	13893	0.14413	0.25
	Type I	Same	5520.02	1373.25	828	17278	0.23567	0.25
		16QAM3/4	5520.02	1378.20	1035	6533	0.02636	0.25
		QPSK3/4	5520.02	1376.85	938	5386	0.00092	0.25

TABLE III. LTE SYSTEM WITH A DISTANCE OF 300 M AND A SPEED OF 80 KM/HR

LTE, Distance = 300m, Speed = 80 km/hr, and Buffer = 1280 Bytes

MSC Data	Retransmission Method	MCS Retransmission Method	Theoretical Data Transmission Rate (kbps)	Actual Data Transmission Rate (kbps)	Greatest Buffer Demands (Bytes)	Instances of Transmission	PER	Data Transmission Ratio
QPSK1/2	Chase Combining	Same	1040.00	933.71	534	3888	0.00005	0.9
	Type I	Same	1040.00	932.94	592	4176	0.00022	0.9
QPSK3/4	Chase Combining	Same	1680.01	1091.11	1126	11500	0.00726	0.65
	Type I	Same	1680.01	1088.44	1271	13103	0.01826	0.65
16QAM1/2	Chase Combining	Same	2320.01	1159.81	1244	16088	0.02521	0.5
	Type I	Same	2320.01	1043.83	1119	18606	0.07253	0.45
		QPSK1/2	2320.01	927.85	1073	9937	0.00574	0.4
16QAM3/4	Chase Combining	Same	3600.01	1259.80	1188	21646	0.09733	0.35
	Type I	Same	3600.01	1079.83	828	23908	0.20366	0.3
		QPSK3/4	3600.01	899.86	1166	13636	0.0777	0.25
64QAM2/3	Chase Combining	Same	4880.02	1214.83	732	60998	0.99993	0.25
	Type I	Same	4880.02	1214.83	732	61000	1	0.25
		16QAM1/2	4880.02	731.88	543	19299	0.25432	0.15
		QPSK1/2	4880.02	727.71	1122	11428	0.01978	0.15
64QAM3/4	Chase Combining	Same	5520.02	1374.15	828	61000	1	0.25
	Type I	Same	5520.02	1374.15	828	61000	1	0.25
		16QAM3/4	5520.02	827.87	621	22273	0.36328	0.15
		QPSK3/4	5520.02	825.16	1125	15309	0.12984	0.15

TABLE IV. LTE SYSTEM WITH A DISTANCE OF 300 M AND A SPEED OF 350 KM/HR

LTE, Distance = 300m, Speed = 350 km/hr, and Buffer = 1280 Bytes

MSC Data	Retransmission Method	MCS Retransmission Method	Theoretical Data Transmission Rate (kbps)	Actual Data Transmission Rate (kbps)	Greatest Buffer Demands (Bytes)	Instances of Transmission	PER	Data Transmission Ratio
QPSK1/2	Chase Combining	Same	1040.00	727.88	620	15145	0.00700	0.7
	Type I	Same	1040.00	727.88	779	17126	0.01803	0.7
QPSK3/4	Chase Combining	Same	1680.01	1007.84	993	22435	0.02352	0.6
	Type I	Same	1680.01	923.85	882	24814	0.05860	0.55
16QAM1/2	Chase Combining	Same	2320.01	1043.83	847	29758	0.08707	0.45
	Type I	Same	2320.01	927.85	676	31921	0.16590	0.45
		QPSK1/2	2320.01	695.89	589	17568	0.06514	0.3
16QAM3/4	Chase Combining	Same	3600.01	1077.71	810	44363	0.40721	0.3
	Type I	Same	3600.01	1077.53	1120	48920	0.53410	0.3
		QPSK3/4	3600.01	719.88	522	22041	0.19738	0.2
64QAM2/3	Chase Combining	Same	4880.02	1214.83	732	61000	1	0.25
	Type I	Same	4880.02	1214.83	732	61000	1	0.25
		16QAM1/2	4880.02	730.80	525	26454	0.50852	0.15
		QPSK1/2	4880.02	487.92	586	12809	0.19820	0.1
64QAM3/4	Chase Combining	Same	5520.02	1374.15	828	61000	1	0.25
	Type I	Same	5520.02	1374.15	828	61000	1	0.25
		16QAM3/4	5520.02	550.74	276	23093	0.89393	0.1
		QPSK3/4	5520.02	551.91	317	15116	0.35033	0.1

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